2.0 Research and Development

Revision Date:
February 11, 2009

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2.1 *Residential Integration*

Table 2-1 summarizes the subprogram's history, including past accomplishments and future direction.

Table 2-1. Residential Integration Summary

Start date	1995
Target market(s)	New, single-family residential buildings
Accomplishments to date	• Developed the Building America Benchmark Definition. • Developed protocols for validating whole house energy tools. • Documented research and publishing Houses That Work, Builder Guides, and Best Practices manuals. • Over 120,000 ENERGY STAR® Homes were built in 2007.[1] • Completed 15% whole house Best Practices. • Completed research in 5 climates at 30% energy savings compared to Building America benchmark. • Completed research in 2 climates at 40% energy savings compared to Building America benchmark. • Completed 41,198[2] Building America houses. • Completed development of builder technology packages for five major US climate regions that produce energy savings of 30-40%. Key system innovations include the development of simple methods for moving ducts into conditioned space, development of flashing, shear panel, and fastening details required to expand use of insulating sheathing, development of new vapor retarder details required to ensure that moisture can escape from high R wall assemblies, development of unvented attic insulation systems, development of high density blow in cavity fill insulation systems, development of preformed window drainage pans to eliminate water leakage around windows, development of low cost polymer solar hot water collectors for non-freezing climates, development of vapor retarder systems for unvented crawl spaces and slab on grade foundations, and development of integrated PV and thermal energy systems. • Four peer reviews have been completed covering all three stages of the Building America research process and also completed a review of major lessons learned from Building America communities.

[1] www.energystar.gov. Accessed September 20, 2008.

Current activities	2009 activities: Developing integrated cost-effective, whole building strategies to enable new, single-family residential buildings to use 40% less total energy than the Building America Benchmark in the Mixed-Humid climate. Completing 40% reductions in Mixed-Humid and Cold climates. Working towards 40% reduction in Hot-Humid climates in 2010.
Future directions	Continuing to develop the strategies, technology packages, and training packages for new, single-family residential buildings to use 40-100% less energy than the Building America Benchmark in the Marine, Hot-Humid, Hot/Mixed-Dry, Mixed-Humid, and Cold climate regions.
Projected end date(s)	2020
Expected technology commercialization dates	See Table 2-4. Residential Integration Efficiency Performance Targets by Climate Region.

2.1.1 Program Overview

The Residential Integration (RI) subprogram, primarily Building America activity, focuses on improving the efficiency of the approximately 1.0 million new homes built each year.[3] These improvements are accomplished through research, development, demonstration, and technology transfer of system-based strategies. The system-based strategies improve whole house source energy efficiency through integrating technologies to achieve reductions in all residential energy uses. The Building America energy efficiency activities support efforts to integrate solar electric and thermal as well as other renewable technologies into buildings, which will result in net-zero energy homes (ZEH).

Working with various partners, Building America will achieve ZEH by 2020 for five climate zones and transfer the results to builders and stakeholders to achieve market penetration of ZEH. These outreach resources include technology package research reports, which represent research results achieving a particular level of performance, and other documentation, form the basis for Best Practices manuals tailored to specific climate regions.

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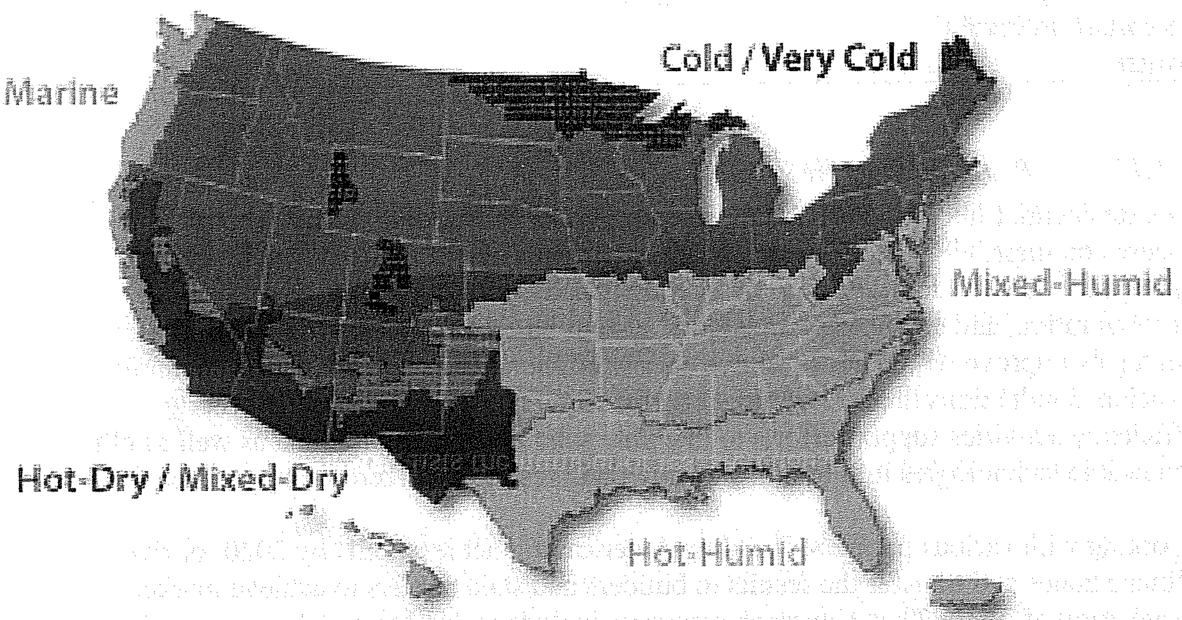
[2] www.eere.energy.gov/buildings/building_america/ Accessed September 20, 2008.
[3] National Association of Home Builders, *Annual Housing Starts (1978-2007)*, 2007. http://www.nahb.org/generic.aspx?sectionid=819&genericcontentid=554&channelID=311, Accessed October 18, 2008.

In order to reach ZEH, Building America has projects in 33 states involving 380 builder partners.[4] Building America directly influenced 472 houses in the first 8 months of 2008 and a total of 41,198 houses over the 11 year program duration, resulting in over a trillion BTUs saved. The ENERGY STAR® new homes program has also directly benefited from Building America research and continues to utilize and promote the research results. Due to the program's outreach efforts at professional and builder conferences as well as with trade press media, the number of homes indirectly built using Building America best practices is far greater, up to the hundreds of thousands.

Unlike other building types, residential buildings include a limited number of different end uses with many similarities in a particular climate region. Therefore system solutions can be replicated on a regional basis. Figure 2-1 shows the climate regions defined by Building America and Table 2-2 lists the number of research houses by region.

Figure 2-1. Building America Climate Regions



[4] NREL, Bob Hendron. Email Communication, September 26, 2008.

Table 2-2. Total Research Houses by Climate Region[5]

Climate Region	Number of Homes
Hot-Humid	3,777
Hot-Dry/Mixed-Dry	24,956
Cold and Very Cold	5,237
Mixed-Humid	926
Marine	1,653

Building America currently focuses on five climate regions: Hot-Humid, Hot-Dry/Mixed-Dry, Cold and Very Cold, Mixed-Humid and Marine. The majority of the research activity is in the Hot-Dry and Cold regions due to the relative number of housing starts in these climates.

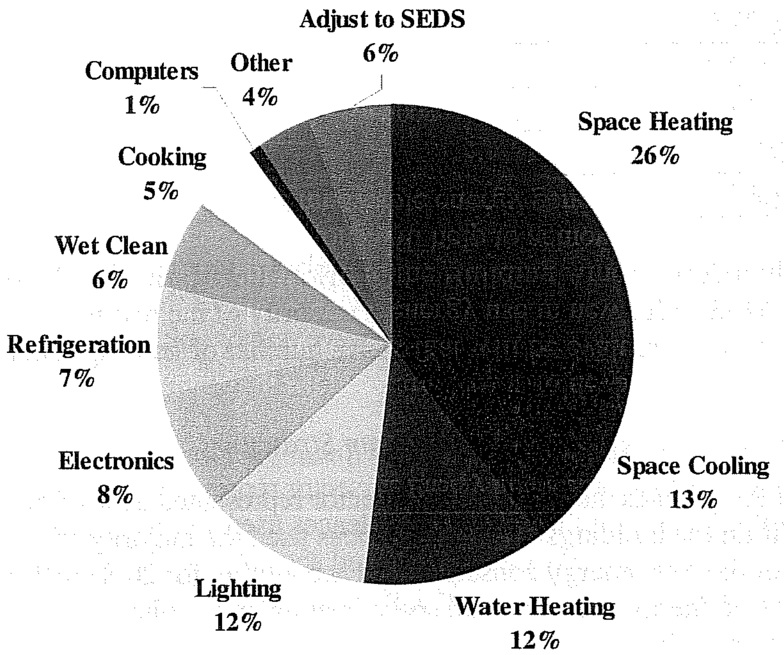
2.1.2 *Residential Integration Support of Program Strategic Goals*

In 2006, the US consumed 99.5 Quads and the buildings sector represented 39% of the total energy consumed. Within the buildings sector, residences used the majority of the energy, representing 54% of the total energy consumed and accounting for 20.8 quads in 2006.[6] The largest end uses of energy in a home are space heating and cooling, water heating, and lighting as shown in Figure 2-2.

[5] Source: NREL 2007

[6] Building Energy Data Book, September 2008.

Figure 2-2. 2006 Residential Buildings Primary Energy Use[7]



Note: SEDS is a statistical adjustment by the Energy Information Administration to reconcile two divergent data sources.

The Residential Integration subprogram goal is to develop integrated energy efficiency and onsite renewable power solutions that will be evaluated on a production basis in subdivisions to reduce whole-house energy use in new homes by an *average*[8] of 50% by 2015 and 70% by 2020 compared to the Building America Benchmark[9,10] at neutral cash flow.[11] These efficiency solutions will help to achieve the strategic goal of ZEH by 2020 when combined with on-site renewable energy generation.

[7] Buildings Energy Data Book, September 2008

[8] The distinction between the average savings and the range of savings is important because it is not cost-effective (or even possible without wasteful over engineering) to design a net-zero energy home for every possible potential occupant. Because the range of possible occupant behavior is large, the average savings target in 2020 is 95%. This average will include a significant number of homes that achieve 100% savings, ensuring that the goal of net-zero energy homes is met.

[9] *Building America Research Benchmark Definition*, Updated December 20, 2007, National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy08osti/42662.pdf

[10] The Building America Research Benchmark Definition consists of the 2000 IECC envelope requirements plus, HVAC, lighting, appliances and plug load energy levels derived from best available research studies and energy use data for 1990's housing stock.

[11] Net cash flow is the monthly mortgage payment for energy options minus the monthly utility bill cost savings. "Neutral" means that monthly utility bill cost savings are equal to the monthly mortgage payment

2.1.3 *Residential Integration Support of Program Performance Goals*

Building America developed the following performance goals for each phase of the systems approach. The performance targets show the energy savings from improvements in efficiency that will be reached on the path to net-zero energy homes in 2020, under the base research schedule. It is feasible to accelerate achievement of these goals by three to four years if additional resources are available.

Table 2-3. Residential Integration Efficiency Performance Goals12

Characteristics	Units	Year			
		2008	2010	2015	2020
Average Energy savings	%	30	40	50	ZEH
Home Owner Cost	$	Neutral Cash Flow			

Building America has also specified the following interim performance targets for each climate region, which also serve as the annual Joule milestones for the subprogram.

Table 2-4. Residential Integration Efficiency Performance Targets by Climate Region

Target (Energy savings)	Marine	Hot-Humid	Hot-Dry/ Mixed- Dry	Mixed-Humid	Cold
40%	Done	2010	Done	2009	2009[13]
50%	2012	2012	2011	2013	2014
70%[14]	2017	2016	2015	2017	2018
ZEH	2020	2020	2019	2020	2020

The performance targets are incremental percentages to manage research risks, closely track progress, and allow early identification and targeting of barriers to achieving the strategic goal. Hence, the Building America systems research strategy increases the

for energy options. In other words, the increase in a 30-year mortgage payment is offset by the energy savings.

[12] Year of completion of annual Joule targets in five climate regions. Energy savings are measured relative to the Building America Research Benchmark. This schedule assumes that funding for the systems research activities will remain at FY 2008 levels.

[13] Current projection is for five cold climate case studies to be completed in 2009. However, due to the economic slowdown and reduction in single family and multifamily new housing starts, completion of one or more cold climate case studies will be completed in 2010. Email from Ren Anderson, September 4, 2008.

[14] The current Building America target year for completion is 2020. Climate zone target dates for the 70 percent level are dependent upon progress at lower target (energy savings) levels and will be determined in a future planning cycle; some climate zones may be completed before 2020.

performance targets leading toward long-term strategic goals based on the successful development of system solutions at the previous performance level. These goals are adjusted and reviewed on an annual basis relative to current year technical progress and barriers.

2.1.4 Residential Integration Program Approach and Management

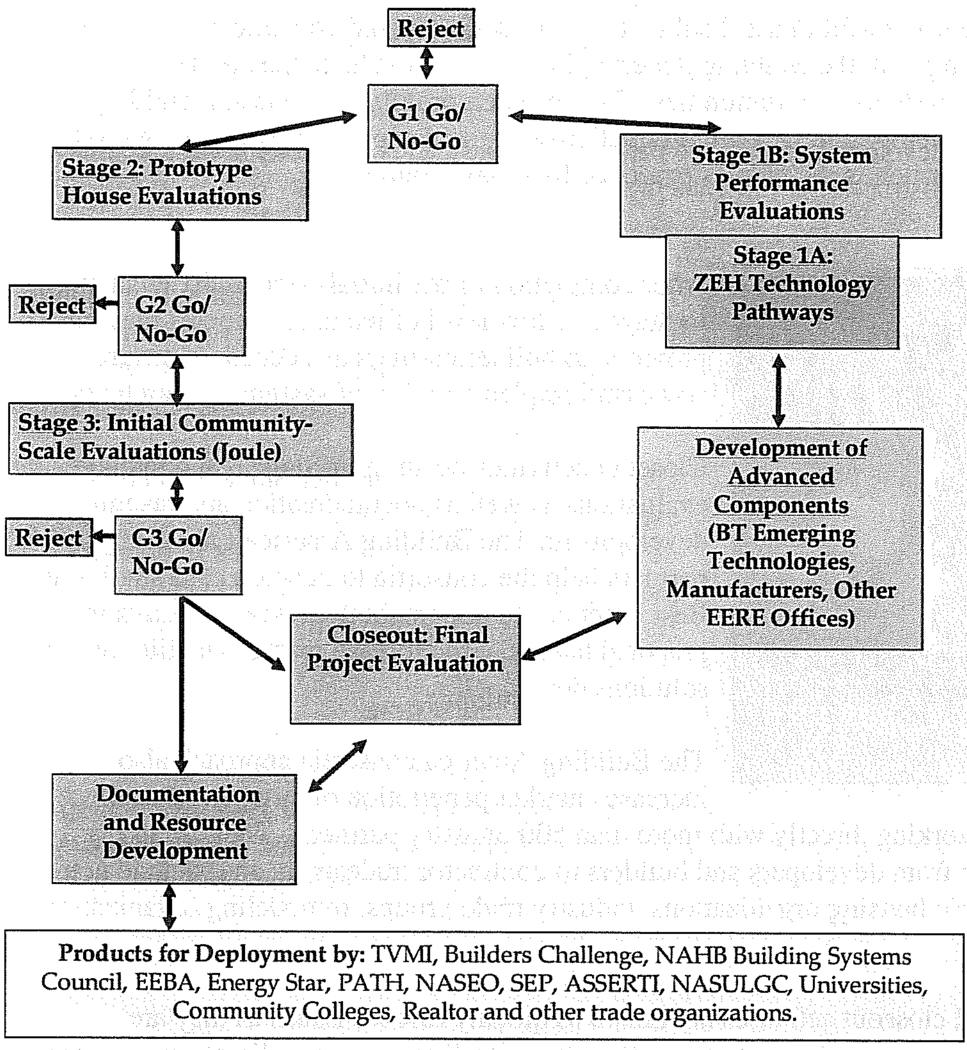
The primary implementation strategy for Building America is to form teams of architects, engineers, developers, builders, equipment manufacturers, material suppliers, community planners, mortgage lenders, realtors, and contractor trades. These teams use a systems research approach to develop production ready energy efficient single-family homes in five climate regions. DOE's six Building America teams are the Building Industry Research Alliance, Building Science Consortium, Consortium for Advanced Residential Buildings, Industrial Housing Project, Integrated Building and Construction Solutions and the National Association of Home Builders Research Center.

In order for energy-efficient solutions to be viable candidates over conventional solutions, they must cost-effectively increase overall home value and quality, while reducing energy use. Building America's systems research approach examines systems cost and performance trade-offs in the context of overall building savings and cost. Alternately, a component research approach would not account for system interactions, creating integration barriers and additional risk in meeting energy savings goals cost-effectively. Moreover, not addressing the house-as-a-system could produce unintended health and safety risks.

By involving stakeholders throughout the process, Building America reduces risk through early identification of problems relating to field installation, manufacturability, and market acceptance. The builders provide the houses and the systems, in Building America's systems research approach. However, Builders themselves are risk-adverse because they do not have the comprehensive research capabilities required to evaluate unproven building technologies or construction strategies. Builders traditionally avoid changes that increase risks, increase costs, have the potential to cause customer complaints, require additional training or oversight of their subcontractors, require use of new and unfamiliar suppliers, materials and/or equipment, require additional planning steps or code approvals, or have the potential to increase future home warranty costs. Through working with Building America, builders can confirm that new approaches and technologies meet minimum requirements for successful integration into new homes. Building America's systems research activities provide the technical support as well as cost and performance documentation that builders require to accelerate technology adoption and implementation of ZEH building practices.

Throughout the design and construction process, these Industry Teams evaluate the interaction between the building site, envelope, mechanical systems, and energy-use factors. This provides the whole-house context required in assessing if a technology can help achieve ZEH goals. Building America uses Stage-Gate management to provide structure to systems research and interactions with the Consortia. There are three stages (with a final closeout stage) for each climate zone with decision points or gates at the completion of each stage as shown in Figure 2-3. To accelerate progress towards multi-year goals, research is conducted in parallel at different performance levels, facilitating rapid use of new system solutions at all performance levels.

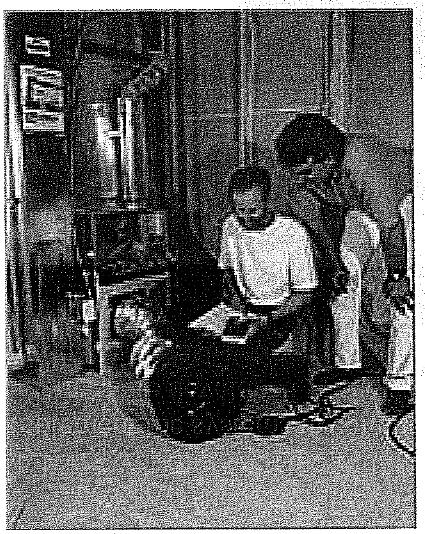
Figure 2-3. Residential Systems Research Stage-Gates



In Stage 1, Building America utilizes operations research techniques to identify the technology pathways that will achieve the target energy savings in each climate region for the lowest installed cost. Parametric studies are conducted using the BEOpt analysis tool to evaluate technology pathways, gaps, and advanced components needed to achieve multi-year performance goals. From these results, the optimal efficiency targets can be identified and technologies can be developed that will meet the energy savings needs cost-effectively in all climate regions.

In Stage 2, the optimal energy-saving technology pathways are implemented in prototype homes. They design, construct and test subsystems to evaluate and field test prototype subsystems to determine the most reliable and cost-effective solution for a given performance level and climate. This step identifies challenges and barriers unanticipated in lab testing.

In Stage 3, the successful Phase 2 subsystems are designed and constructed by production builders working with the Building America Consortia to evaluate the ability to implement the systems in communities. The research prototype house and building practices are developed so they are production-ready and capable of being integrated with production construction techniques practiced by today's builders.



After completion of the initial community evaluations in Stage 3, a low level of technical support may be provided to builder partners as needed, to ensure successful implementation of systems research results.

Closeout activities occur after Stage 3 and include evaluations as well as documentation and resource development. The Building America Laboratory partners help the consortia to develop case studies and Best Practices to document the research results in practical language to increase market viability of the solutions developed.

The Building America consortia approach also increases market penetration of systems research solutions by working directly with more than 500 industry partners. These Industry Partners range from developers and builders to contractor tradesmen, and include non-profit affordable housing organizations, industry trade groups, remodeling organizations, and others.

The stages and closeout activities are linked to quickly resolve issues as they are identified. These research stages currently take up to five years per climate region, and for more advanced energy efficiency levels (above 40% savings), the process is expected to take additional iterations of whole house testing before implementation in production ready homes. At and above the 50% level, the systems research stages may take up to six years to complete each climate region.

As Building America system research activities begin to target the 50%+ performance levels, unoccupied laboratory homes will be used to provide extended full scale testing of emerging technologies under controlled conditions. The cost of construction of laboratory homes will be sponsored by Building America's industry partners. Unoccupied laboratory homes will allow more extensive control over design specifications, equipment installation, monitoring instrumentation, and operating conditions than are possible in homes that have been built for immediate sale. They also allow testing of emerging technologies so manufacturers can be more directly involved.

2.1.5 Identification of Component Development Needs

The BT management approach requires early identification of future system needs to allow for sufficient lead time necessary for developing and evaluating new options to meet those needs. Prior to starting Stage 1b systems evaluations, components must be developed and then evaluated to determine if they can fill gaps between current systems' performance and future whole house performance goals. These components are developed in collaboration with industry partners, BT, and other EERE offices. The component research requires significant lead time in some cases and focuses on communication of system integration needs and requirements to component developers. Building America's role is providing inputs to component developers that help to identify residential system integration needs, requirements and gaps based on annual residential cost/performance studies using the BEOpt analysis method.[15,16] Components that move from development to Stage 1b system evaluations must meet minimum requirements for energy performance, reliability, and cost-effectiveness before they are included as part of the residential integration activities in Stages 2 and 3.

Critical path technologies are required to achieve cost effective Zero Energy Homes and reach long term research goals. Minimum performance and cost targets[17] include:

- <u>High R Wall Systems</u>: Durable high R wall systems for cold, northern marine, and mixed climates, leading to development of an R-30+ wall assembly with an *incremental cost of $2/ft2-floor area* relative to an R-19 2x6 wall.

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[15] Anderson, R., Christensen, C., Horowitz, S., Analysis of Residential Systems Targeting Least-Cost Solutions Leading to Net-Zero Energy Homes, ASHRAE Transactions, 2006.
[16] Anderson, R., Christensen, C., Horowitz, S., Program Design Analysis using BEOpt Building Energy Optimization Software: Defining a Technology Pathway Leading to New Homes with Zero Peak Cooling Demand, ACEEE Summer Study, 2006.
[17] Cost performance targets were established using BEopt default cost data assuming future PV costs of $3.30/watt. Analysis was done for a west facing 2500ft2 house with 16% window area. "Neutral cost" means that a homeowner moving from a 1990's house into a new home will have the same energy related costs (utility bills plus financing costs for energy upgrades) as they had in their old house (utility bills only). Incremental costs were evaluated relative to IECC 2003.

- Cold Climate DHW: DHW system with *$2000 incremental system cost* and 30% reduction in annual energy relative to a gas tankless hot water system with EF=0.8.
- Cold Climate R10 Window Assembly: R10 window assembly with SHGC of 0.3 and cost of $20/ft2 (*incremental cost of $4/ft2 relative to current low-e windows*).
- Very High Performance AC: AC system with 30% reduction in annual energy use and *an incremental cost of $1000* relative to current SEER 18/EER 13.4 system.
- MELs Reduction: 30% reduction in miscellaneous electric energy use at an *incremental cost of $1000.*

In addition to the component needs above, Building America has identified and is developing systems integration objectives. For the HVAC systems, Building America seeks high installed performance in terms of overall energy efficiency and part load performance. There are similar objectives for hot water systems, for example, to reduce distribution losses and improve overall system efficiency. As these objectives are met through improved systems, Building America will achieve production home building processes that meet comfort, safety, health and durability goals.

2.1.6 Residential Integration Barriers and Strategies

The residential sector is the largest user of energy for buildings, and single-family homes currently consume approximately 80% of the energy used for residential buildings. Homes are significant contributors to the growth of peak electric demand during the cooling season because of the high penetration of air conditioners. Not only do single-family homes account for four-fifths of the residential energy use, but over the next decade the single-family home sector is projected to grow and account for over 70% of new housing units.[18] Building America targets single-family homes because of this energy use and likely large growth in energy use. Technologies developed for single-family homes can often be applied to multi-family, manufactured, and existing homes.

In addressing homes, Building America has identified barriers to achieving ZEH and subsequently developed strategies to address these barriers. In order to meet the strategic and performance goals, Building America must implement the strategies listed in Table 2-5 to address the barriers.

[18] Berson, David, et al, *America's Home Forecast: The Next Decade for Housing and Mortgage Finance*, 2004, Homeownership Alliance.
http://www.homeownershipalliance.com/documents/americas_home_forecast_005.pdf

Table 2-5. Residential Integration Barriers and Strategies

Barrier	Title	Description	Strategy/Solution
Management, Stage-Gate, & Analysis			
A	Residential Pathways	Homes are complex and it is difficult to evaluate potential energy savings technologies in terms of performance and cost.	**BEOpt Modules** – Add modules to increase BEopt capabilities and fully integrate EnergyPlus. **Technical Pathways -** Evaluate technology pathways, gaps, and tradeoffs.
B	Laboratory Houses	Some technologies are too risky to install in production homes.	Design laboratory houses that will be used for testing and monitoring high risk designs aimed at 50-70% savings.
C	Prototype Houses	Uncertainty if technologies will achieve desired performance levels when installed in houses.	Install new technologies into prototype houses and evaluate systems interaction and energy performance.
D	Community Scale Houses	Scalability challenges as systems move from a prototype house to subdivisions.	Provide technical support to builder partners and document system design and construction practices that achieve target energy savings levels.
E	MELs Analysis	No means of prioritizing MELs reduction approaches.	Produce a parameterized equation that can estimate MELs energy use. This data will be used in home energy ratings and to best determine how to reduce MELs energy consumption.
F	Retrofit Analysis	No standard method to estimate energy savings from retrofit measures and current methods are time consuming.	**Best Test Ex** - Develop a method to test different analysis approaches and investigate the minimum input data required to accurately predict energy savings of retrofit measures. **Utility Bill Basis for Escale** - Determine how to best use utility bills to produce a home energy rating, using an E-Scale.

Systems Research & Development: Envelope, Windows, Doors			
G	High R Walls	Moisture problems as well as thermal and durability issues	Use field work to develop moisture solutions. Improve whole wall performance and increase collaboration with industry and the Envelope subprogram.
H	Advanced Foundations Subsystems	High costs and installation challenges. Key published guidelines are out of date and sometimes contradictory.	Utilize advances in new materials and improve system design to develop easy to install advanced foundation subsystems. Develop a consensus-based electronic source book that supports best practices, industry guidelines, and codes.
I	Windows	Insulation and solar heat gain properties do not achieve target levels.	Work with the Windows subprogram, laboratories, industry and Canadian programs to develop and test new technologies that achieve R-7 to R-10 Window Systems.
Systems Research & Development: HVAC and Water Heating			
J	Condensing Water Heaters	Control is difficult and designs do not adequately address solar integration, low capacities, and high costs.	Develop control strategies to ensure water heaters operate in condensing mode and lower the capacity of systems while maintaining efficiency. Focus on cost-reduction strategies and integration with solar systems.
K	Low Loss Hot Water Distribution	Energy savings potential of low loss hot water distribution systems is unclear.	Analyze the potential energy savings of low loss hot water distribution systems.
L	High Performance Space Conditioning	The installed performance of heat pumps and AC is insufficient for high performance homes. Areas needing improvement include: dehumidification for both comfort and health; peak load and demand response; partial load efficiency; cost effective high SEER/EER	**Efficient Dehumidification** – Refine and test approaches to dehumidification with appropriate sensible and latent load ratio. **Space Conditioning for High Performance Homes** - Advance approaches to maintain efficiency while reducing capacity, such as cost-effective variable speed compressors.

		variable capacity (between 1-4 tons); and, improved diagnostics and sensors to aid in commissioning and maintenance.	**Ventilation Air Distribution Study** – Identify areas of improvement in duct systems and distribution systems.
M	Indoor Air Quality	Lack of detailed understanding of indoor air quality problems and the role of air distribution systems	Collaborate with the EPA and HUD and analyze integration of outside air delivery with home space conditioning systems as well as other IAQ strategies
Systems Research & Development: Miscellaneous Electric Loads, Storage, Controls, Load Management			
N	Miscellaneous Electric Loads	Lack of clear strategies to reduce MELs.	Determine opportunities for increased energy efficiency, whole house controls and peak load reduction and implement in lab houses.
O	Thermal Storage	There is a lack of understanding concerning how to properly integrate thermal storage systems and building HVAC systems.	Collaborate with EERE programs in analyzing and building the understanding of what is needed to develop thermal storage systems.
P	Solar Electric and Thermal Systems	There is a need for cost reductions and better systems engineering between the solar and building systems.	Collaborate with the Solar Energy Technologies Program and the Solar Heating & Cooling subprogram to test and analyze solar integration activities, resulting in marketable systems by 2015.
Q	Controls	Home energy management systems available on the market do not provide adequate energy savings.	Develop algorithms for Home Automation to reduce household energy use. Include: feedback capability, adaptive controls, additional mass, utility interaction, critical peak pricing, and plug and play features for solar inverters for new and existing homes.
Systems Research & Development Additional Housing Market Sectors			
R	Existing Homes	There is a lack of understanding concerning how to accomplish large	**Existing Homes R&D** - Develop energy savings packages for various house configurations and

		energy savings in existing homes, which meet adequate health, safety and durability criteria. Also, current technologies and practices are expensive.	outline a plan to move from 20% savings to ZEH for existing homes. **Deep Retrofits** - Create 40% and 50% savings Best Practice manuals and Builders Challenge guides, and provide this information to the public. **Attics and Roof Retrofits -** Research possible retrofit strategies, as well as duct, attic stair and hatch insulation approaches.
S	Affordable Technologies	Energy saving technologies are cost-prohibitive in affordable housing.	**Safe Affordable Housing Technologies -** Develop test procedures and design tools to enable code acceptance and market adoption for safe, affordable subsystems.
Market Development and Outreach			
T	Builder Incentives	Industry leaders and practitioners are skeptical about the performance, cost, and practicality new systems.	Through Builders Challenge, conduct builder outreach and provide support to promote and reward building energy efficient homes.
U	Builder Resources	Industry leaders do not have access to information on the most current and efficient building's technologies and procedures.	Document best practices and case studies that will be used by builders as well as in curriculum.
V	Existing Homes	Existing homes are in great need of improvement, but homeowners are unaware of the benefits of energy efficiency.	Through Home Performance with ENERGY STAR, work with utilities and state energy offices to train contractors to improve homes and provide incentives for both homeowners and contractors.
W	Quality Management Tools	The integration of building science and quality management is needed to build high performance communities.	Develop trade design and construction documentation and other resources for builders. Also, provide an analysis of the economics of quality management.

Construction of new homes requires the combined efforts of numerous suppliers and contractors whose efforts are coordinated by a large number of builders. Because of the high costs of failure, the residential construction industry is highly risk-intolerant and first-cost sensitive. Retrofitting existing homes has many of the same risk-intolerance and first-cost sensitivities of the new homes market, with the additional barrier of fragmented nature of the market.

The key barriers to development of advanced residential energy systems are the large number of market players, the relatively low level of investment in R&D relative to other sectors of the economy, the strict requirements for market acceptance based on achievement of low incremental costs and high reliability, and the large number of technical performance requirements that must be met before a new system can be implemented on a production basis.[19]

2.1.7 Management, Stage-Gate, and Analysis Activities

Management and Stage-Gate activities are linked, effectively implementing the Building America Consortia strategy as described in Section 2.1.4 Residential Integration Program Approach and Management.

The National Renewable Energy Laboratory (NREL) serves as the technical integration manager for all Building America activities overseeing all of the research products and directing the Building America Teams' research activities. The technical manager assesses cost-performance tradeoffs; develops strategies to increase home durability; determines technology gaps and provides performance specifications; identifies critical performance requirements by climate region; and defines the least cost combination of technologies. The following meetings are critical to effective Building America management:

- Quarterly Meetings where the technical manager reviews project plans and ensures teams maintain technical coordination
- Peer Reviews where teams present their target goals and are evaluated by a panel based on the stage gate criteria.
- Expert Meetings are strategic planning tools to provide outside peer review of current Building America activities. These meetings identify gaps, potential partnerships, and research priorities.
- Working Groups address longer term research and other activities, and can provide for on-going coordination among emerging technology research, systems

[19] These technical performance requirements are driven by regional differences in building energy loads and construction techniques. For example, systems that work well in cold climates may not be applicable in hot climates

integration, and code activities. Working groups engage experts in meetings and less formal forums on their areas of research.

Management activities also include evaluation of houses for each of the gates as well as long-term monitoring and analysis. These activities ensure that target performance levels are achieved in all climate zones.

Analysis activities occur as needed to support program prioritization, develop strategies, and fill knowledge gaps. Long-term analysis activities, such as developing and enhancing the BEOpt tool, shape program goals through modeling. Results from BEOpt identify the technical pathways, allowing Building America to assess tradeoffs and develop optimized solution sets. Additional analysis activities include:

- MELs Studies
- Existing homes modeling and tools

2.1.8 Systems Research and Development Activities

Systems R&D activities build from results developed in the emerging technologies programs and are incorporated into lab, prototype, and community-scale houses. In these houses, the Building America consortia evaluate system performance and identify installation and other non-energy related barriers to implementation in ZEH. Building America uses the technical pathways as a roadmap to direct R&D to reach the ZEH performance targets. DOE's national laboratories: Lawrence Berkeley National Laboratory (LBNL), Oak Ridge National Laboratory (ORNL), Pacific Northwest National Laboratory (PNNL), and NREL provide core technical capability for this research.

2.1.9 Market Development and Outreach Activities

<u>Documentation and Resource Development</u>

Market Development activities focus on creating usable resources for builders and other stakeholders that convey lessons learned through Building America research. During and upon the completion of closeout activities, BT fosters market implementation of Building America research and building techniques, and establishes voluntary collaborations with housing and financial stakeholders to make the nation's houses more energy-efficient and affordable. The final activities of the research process include documentation of Best Practices manuals as well as development and evaluation of resources to provide BT research findings to private and public sector training and implementation programs.

At the completion of Stage 3, the research results are documented in technical research reports that serve as references for students, educators, building scientists, architects, designers, and engineers. For the research results to be successfully transferred to key stakeholders in the housing industry, they must be translated into a format appropriate for dissemination to developers, builders, contractors, homeowners, realtors, insurance companies, and mortgage providers.

The Building America resource development effort creates "Best Practices" Manuals, Builders Challenge Guides, and special case studies. These manuals summarize best practice recommendations in illustrated text that is targeted to a specific audience, synthesizing research findings into energy-efficient processes for the building industry. To facilitate construction of affordable homes designed for non-profit organizations and small builders, BT has floor plans and section details available through the BT website and other means.[20]

These efforts document Building America's best practices and lessons learned in over 40,000 energy-efficient new houses of all sizes, styles, and price points, constructed to date by Building America partners. Key Building America research results have also been incorporated in over 781,559 additional homes via coordination with deployment partner ENERGY STAR New Homes Program and even more though industry programs i.e. 900,000 additional homes via coordination with MASCO Environments for Living Program. The first Best Practices volume has documented practices for construction of energy-efficient houses at the 30% savings levels in all climate regions and has illustrated the results through case studies. As Building America efficiency goals increase between now and 2015, similar documentation packages will be developed for whole-house conservation and renewable energy generation levels of 40% and 50%. The current schedule for development of Best Practices is shown in Table 2-6. The documents allow a handoff of BT's building research findings to the private sector.

Table 2-6. Residential Best Practices Schedule

Performance Target	Marine	Hot-Humid	Hot/Mixed Dry	Mixed Humid	Cold
40%	Done	2011	Done	2010	2010
50%	2013	2013	2012	2014	2015
70%	2018	2017	2016	2018	2019
ZEH	2021	2021	2020	2021	2021

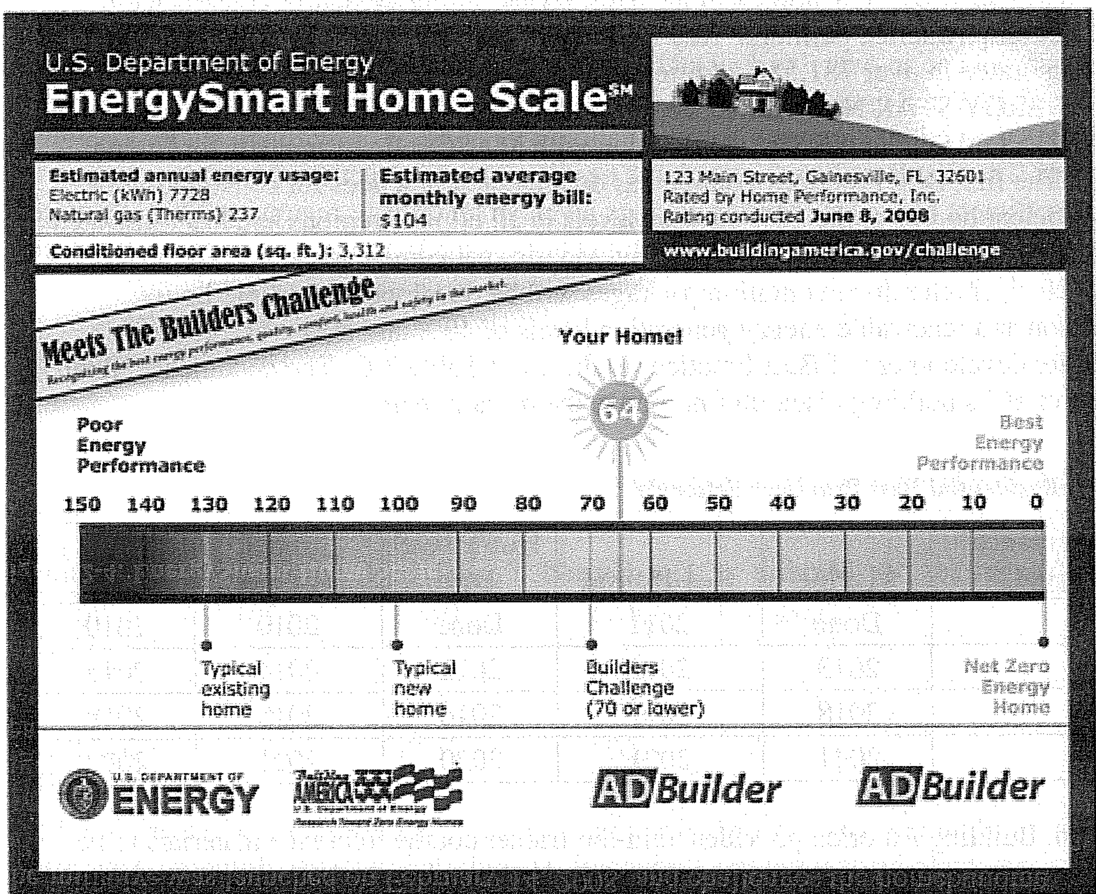
In addition, Building America provides train-the-trainer course reference materials to be used by existing training programs throughout the building industry. Building America provides these reference materials in partnership with ongoing training programs sponsored by professional organizations, universities, community colleges, vocational schools and others involved in the education and training of those associated with the design and construction of homes.

[20] See www.buildingscience.com/doctypes/primer/.

Builders Challenge

The Builders Challenge is a market transformation initiative that is based on Building America R&D and provides incentives for builders to build high performance homes. The initiative was launched on February 14, 2008, and challenges the homebuilding industry to build 220,000 high performance homes by 2012. Homes that qualify for the Builders Challenge must be 70 or lower on the EnergySmart Home Scale (E-Scale, Figure 2-4) and meet the Builders Challenge Quality Criteria, which addresses durability, health, and safety. The E-Scale, which is based on the Residential Energy Services Network (RESNET) HERS Scale, provides a national metric and gives consumers an easy way to compare the energy efficiency of homes.

Figure 2-4. EnergySmart Home Scale



As higher performance technologies become commercially available, the Challenge level will move closer to ZEH. The Builders Challenge goal of market ready ZEH in 2030 (Table 2-6) lags behind the Building America program so it can leverage proven R&D

results, and also address other efforts, such as raising the efficiency levels in ASHRAE standards.

Table 2-6. Building America Goals

Initiative Goals	2012	2030
EnergySmart Home Scale (E-Scale)	70	0
Cumulative # of Homes from 2008	220K	1.3M
Cumulative Energy Savings (Quads, Primary)	0.015	0.178
Cumulative Energy Cost Savings	$143M	$1.7B
Cumulative Carbon Savings (Million Metric Tons)	0.231	2.799

Key elements of the Builders Challenge initiative include:

- Consumer education campaigns that will provide builders, Realtors, and others with targeted marketing messages to homeowners. Outreach strategies will be developed to showcase the benefits of participating in the Challenge.
- Builder outreach and support will promote and reward participation. Support for builder participants includes a network of partners and existing programs (e.g. RESNET, NAHB Green Building Guidelines, Earth Advantage, Environments for Living, etc), online technical expertise, training resources, marketing toolboxes to make it easier to build and sell high performance homes to consumers; and recognition for industry leadership.
- Partnerships with existing national, regional, state and local programs and stakeholders cultivate effective, collaborative processes to design and deploy the technical support and marketing tools that will reduce the cost and complexity of achieving high-efficiency homes; build public awareness of the benefits of high performance homes; and verify actual performance of these homes.
- Two design challenges will identify and recognize leading high performance home designers and make appealing energy-efficient designs readily available and build-able for builders. To facilitate builder recognition, the Builders Challenge Criteria will be incorporated into EHVA awards. Builders Challenge will also create an online design contest which will be open to architects, designers, students, etc.
- Plans for a builder recognition program will be developed in FY 2009 and could include a Cabinet-level award or a monetary prize for extraordinary contribution to residential energy efficiency.

Home Performance with ENERGY STAR

The Home Performance with ENERGY STAR (HPwES) program is jointly managed with EPA and it aims to improve the 100 million existing homes in America. The program goal is to increase the energy performance of a total of 15 million existing homes by 20% by 2030, which represents cumulative savings of 4.4 Quads with energy savings of approximately $6 billion (2006 dollars). Ideally the strategies used to reach the 2030 goal will lead to measures that will retrofit millions of homes per year in order to achieve a much larger annual energy savings.

The HPwES program currently recruits local sponsors (utilities, state energy offices and not-for-profit organizations) to recruit and train contractors who will conduct energy efficient retrofits. As of FY08, approximately 20,000 homes have been improved through HPwES in 23 states, and in California, all four investor-owned utilities have or are launching HPwES programs, which represents 5% of the U.S. population. HPwES plans to support and recruit 5-10 locally-sponsored programs while launching a pilot to make HPwES available nationally.

DOE and EPA will promote an aggressive pace for improving existing home energy performance though the following key activities:

- Supporting local HPwES program launches by providing training, infrastructure, quality assurance and financing to utilities, state energy offices and other non-governmental organizations.
- Establishing collaborations with national retailers and manufacturers to promote home energy audits and home performance retrofits as well as provide QA. In 2009 and 2010, DOE and the EPA will identify interested national companies and several local regions for pilot projects that will benefit from the additional services and sales from HPwES.
- Developing financing by encouraging utilities and other large companies to use the DOE loan guarantee program to develop widely available home loans for energy efficient retrofits. HPwES will also work with traditional home financing companies to develop financing solutions for homeowners to improve the energy performance of their homes and reduce their energy costs. These loans could be a powerful economic stimulus for the American economy since the investments and the jobs stay in local communities.
- Developing a quality assurance program in collaboration with Building Performance Institute (BPI) and RESNET, national companies, utilities and other independent third parties to ensure that the home improvements are of high quality and delivering energy savings.
- Providing easily accessible on-line training in building science and energy efficiency improvements for contractors interested in energy efficient home improvements The more than 500,000 companies providing services in the home improvement industry could take additional training to become field certified by BPI and RESNET.
- Exploring community and neighborhood-scale energy efficient improvements to take advantage of economies of scale. Entire communities could become 20% or more energy efficient with targeted marketing, incentives and product sales. BT will contact utilities and local governments to identify approaches for servicing whole neighborhoods within local jurisdictions.

- Providing sales and marketing assistance to sponsors and participating contractors via the ENERGY STAR web site. The EPA also has developed a sales and marketing course for contractors which should be incorporated into an on-line course.
- Developing a simplified home rating tool (software, spreadsheets, manual) that uses utility bills and a simplified set of home measurements to determine home energy savings and streamline the analysis. Also developing a software-driven quality assurance checker for RESNET providers and BPI affiliates.
- Pursuing research that supports the 2030 goal as well as research into methods to provide deeper energy reductions with the long-term goal of zero-energy retrofits. This includes optimizing energy savings packages for 20% savings, identifying technical pathways to ZEH for existing homes (both incremental and single renovation), and strategies for cost-effective deep energy retrofits. Building from this, develop energy savings packages for communities with the same vintage and style of homes and produce case studies.
- Coordinating a Homeowners Challenge to increase the energy efficiency of existing homes by 30 points on the E-Scale. This initiative will be modeled on the Builders Challenge, but will impact the 110 million existing homes.

Zero Peak Community Utility Benefits

Working with utilities early in a major subdivision or development provides the opportunity to acquire utility bill data for post occupancy evaluation, ideally compared to a control group subdivision. Ultimately, as smart meters and/or automated energy management systems are used extensively this will provide another means of data collection.

Utility data shows that highly energy efficient homes with about 2 kW of PV have reduced summer peak loads about 27% from about 2.6 kW to 1.9 kW on a subdivision basis.[21] By combining much greater energy efficiency, automated energy management and larger PV systems, these communities could greatly reduce peak load on the grid. With an automated and weather forecast connected control system, the houses in the communities could be pre-cooled in the morning, maintain this temperature in the early afternoon, and during the utility 2-4 hour peak period, increase the thermostat 2-3 degrees above normal resulting in a reduced load on the grid. In addition, the automated energy management system could moderate impacts on the grid by dropping loads as clouds or other interruptions occur. The utility impact of these advanced energy efficient communities will be a significant peak reduction and avoidance of expensive power purchases on the spot market.

[21] Zero Energy Homes – Transforming Sacramento's New Home Market, Presentation to DOE on March 31, 2008 by Mike Keesee, SMUD.

2.1.10 Residential Integration Milestones and Decision Points

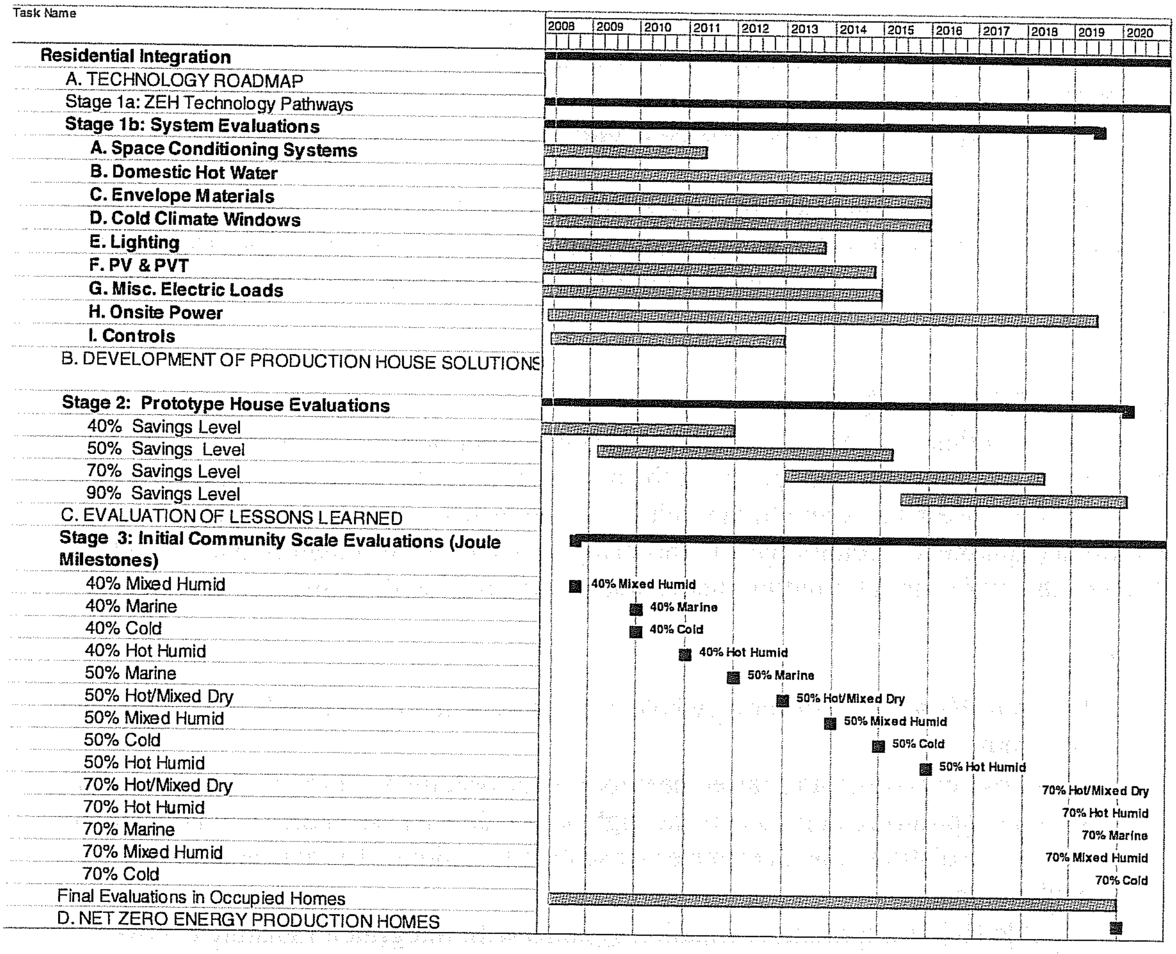
The Residential Integration subprogram will undertake the tasks in the Table 2-7 to address the market and technology barriers and to meet the performance targets. The tasks are listed by stages and duration.

Table 2-7. Residential Integration Whole House Tasks

Task	Title	Duration	Barriers
1	Stage 1A – ZEH technology pathways	2009-2020	A, E-F, R
2	Stage 1B – System performance evaluations	2009-2019	B, G-M
3	Stage 2 – Prototype house evaluations	2009-2020	C, G-M, P, Q
4	Stage 3 – Initial community-scale evaluations (Joule)	2009-2020	D, G-M
5	Closeout: Final project evaluations; Documentation and Resource Development; and Market Transformation	2009-2020	R -W
^	Lab Houses	2009-2020	B, N-Q

The Residential Integration performance targets and tasks can be translated into a schedule that incorporates the Stage-Gate process. Figure 2-5 below shows the schedule for whole house and component tasks. The end of each task is the milestone and also where the Go/No-Go decision occurs for the next stage. The completion of Stage 3 is the point where Best Practices documentation and training materials are developed and tested prior to distributing to implementation partners.

Figure 2-5. Residential Integrated Gantt Chart



2.1.11 *Residential Integration Unaddressed Opportunities*

The Residential Integration subprogram has identified several areas of unaddressed opportunities, which fall into three categories:

- Accelerating ongoing research to be completed sooner
- Expanding research activities to address lower priority tasks on the technical pathways
- Expanding from new, single family homes into other housing markets

Current activities, as listed in the strategies column of Table 2-5, could be accelerated to achieve targeted performance goals in the climate zones sooner and thus realize the energy savings sooner. Another strategy might be to accelerate activity in a particular climate zone to bring solutions market in areas with significant growth. Both would allow for meeting ZEH goals in an accelerated manner.

The current research could be expanded to address existing homes; while 1-2 million new homes are built each year, over 110 million existing homes consume the vast majority of the energy in the residential sector. Particularly attractive is existing homes whole building research, which would begin to address the home improvement market's incorporation of energy efficiency techniques and solutions. Additional market segments such as multifamily or affordable housing could also be considered in depth.

Residential Integration has prioritized the technical pathways and subsequently divided the unaddressed research opportunities and challenges into two levels of priority as defined below.[22] Additionally, within each priority, needs are subdivided by technical categories.[23]

Priority 1- Emerging ZEH Systems

Technologies in this category are modifications of current products to meet ZEH cost and performance requirements and are given the highest priority because they are expected to have the lowest overall risk and highest chance of significant cost sharing with development partners. Technologies in this category have low to medium risk and NREL estimates that with enough funding there could be six successful projects in this area.

Envelope

- R-7 to R-10 window systems (whole window R-value including IGU, edge seals and frame
- Low-cost, easy-to-install raised heel roof truss systems for high R attic insulation systems, optimized approach using high or low density perimeter foam plus blow-in fiber insulation. Fast, perimeter air sealing techniques for new and retrofit applications.
- Durable R-10+ basement foundation systems with integrated moisture control. Durable, low cost slab insulation systems with integral under slab and edge capillary break
- Very high R (R-40+) sealed attic insulation/roof replacement retrofit strategies for existing homes in hot/dry climates with AC and ducts in attic
- Durable, R-30+ wall systems (framing, vapor retarder, insulation, drainage plane) rated as a complete system, rather than a series of components. Needs to address thermal, moisture, air, structural, and bugs.). Insulating wall sheathing that eliminates need to use OSB for structural purposes (structural external insulating sheathing). Efficient siding attachment systems for use with thick insulating sheathing. Low cost SIPS

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[22] Maximizing Residential Energy Savings: Net Zero Energy Home (ZEH) Technology Pathways, Ren Anderson and Dave Roberts, National Renewable Energy Laboratory, November 15, 2008, NREL TP-550-44547.

[23] Note, the source for all of the needs identified below is *Maximizing Residential Energy Savings: Net Zero Energy Home (ZEH) Technology Pathways.*

Water Heating

- High performance condensing hot water heating systems with integrated solar storage, hydronic heating and EF 0.95+ when used in space heating mode
- Simple, low cost, standardized, combined solar hot water (70% solar fraction) and space heating (30% solar fraction) systems for cold climates. Gas tankless, gas tankless/electric hybrid, or super-efficient small tank gas DHW systems that work well with solar preheat systems

Lighting, Appliances, and Miscellaneous Electric Systems

- Low cost whole-house occupancy-based energy control systems with integrated thermostat, ventilation, lighting, home office, peak electric demand, home entertainment control, whole house sleep mode, and low standby power requirements (self-powered wireless, ….) with standardized dashboard allowing for centralized viewing & control of all electrical usage (e.g. lighting, appliances) with the ability to program appliance usage (daily, weekly, monthly, vacation)

HVAC

- Air conditioners with efficient dehumidification modes to limit high interior RH excursions during periods when space cooling is not required.
- Efficient, low volume, air handlers with air tight cabinets and durable, air tight dampers. Integrated ventilation air heat recovery and night venting capabilities for low load homes. Durable, low leakage, low noise, modest pressure drop, small-diameter (3.5"), high-velocity (600 fpm) air distribution systems for easy I-joist integration. Installation guidelines to ensure adequate air distribution and air mixing for thermal comfort. The above systems should be integrated with low capacity (20kBtu) 95%+ efficient furnaces.

Storage

- Building-integrated thermal storage (4-8 ton hours) for homes with very high performance envelopes. Maximize use of existing sensible storage by locating insulation outside of the structure of the building.

Systems Integration

- High efficiency (50% energy savings) retrofit processes that consider envelope air sealing, moisture control, duct sealing, low or variable capacity HVAC systems, integrated ventilation systems and very efficient windows.
- Research on multi-family party walls with good air sealing, insulation, moisture handling and noise reduction.
- Homeowners' operations manual for energy efficient operations and good maintenance.

Quality Assurance:

- Low cost high performance quality management tools and procedures, including model design/construction documentation, training packages, and guidelines.
- Commissioning procedures to ensure that controls and equipment work correctly and are installed well.

Priority 2 - Advanced ZEH Concepts

Technologies in this category have higher risk than priority 1 technologies and will be less likely to have cost sharing from development partners. Successful advanced concepts may provide higher benefits than modifications of current products and NREL estimates that with enough funding there could be two successful projects in this area. Technologies in this category have medium to high levels of risk. To move these activities forward Residential Integration will assess the technical risk, energy savings potential and estimate the product costs.

Lighting, Appliances, and Miscellaneous Electric Systems:

- Efficient direct-DC power systems for HVAC, home entertainment and home office equipment. Including standardized low-voltage protocol and wiring system with central efficient rectification for DC electronics and lighting as well as battery recharging applications.

For the following advanced lighting, appliances and miscellaneous electric system concepts, the benefits are not clear, additional system modeling is needed.

- Improved occupancy sensors (reducing false positives and negatives) for plug, HVAC zoning, and lighting control
- Efficient, smart grid capable appliances and HVAC equipment with integrated diagnostics and energy control modes.

Envelope

There are no advanced systems with either high system benefits or that require additional modeling to determine the benefits.

Water Heating

Benefits are not clear – additional system modeling is needed in the following:

- Low-lift CO_2 heat pump hot water heater, COP 2.0+, 130-150F delivery temperature, for combined hot water and space heating applications.
- Solar-assisted heat pumps for hot water applications with variable lift control to optimize performance over a broad range of input temperatures.

HVAC

- Compact, integrated desiccant dehumidifier and evaporative cooling heat and mass exchanger driven by solar and waste heat (DEvap)

For the following advanced HVAC concepts, the benefits are not clear, additional system modeling is needed:

- Solar-assisted heat pumps for space heating applications with variable lift control to optimize performance over a broad range of input temperatures.
- Roof integrated PV/thermal space heating and night cooling systems (collector+balance of system)

Storage

Benefits are not clear – additional system modeling is needed in the following:

- Desiccant-based thermal storage for simultaneous increased energy density of heating and cooling storage on a single home scale.
- Super capacitor storage.
- Fly wheel storage.
- Super-efficient battery storage.
- Plug-in electric or hybrid vehicles with controls to allow user to optimize overall energy use and cost benefits of vehicle battery storage.

Community Energy Systems

Benefits are not clear – additional system modeling is needed in the following:

- Efficient community-scale residential energy systems including generation, distribution and energy storage (cogeneration, district heating and cooling, wind power, concentrating solar thermal, biomass power systems, solar thermal systems with seasonal storage).